U.S. Air Force Alternative Fuel Efforts:

Fischer-Tropsch and Beyond

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Propulsion Directorate

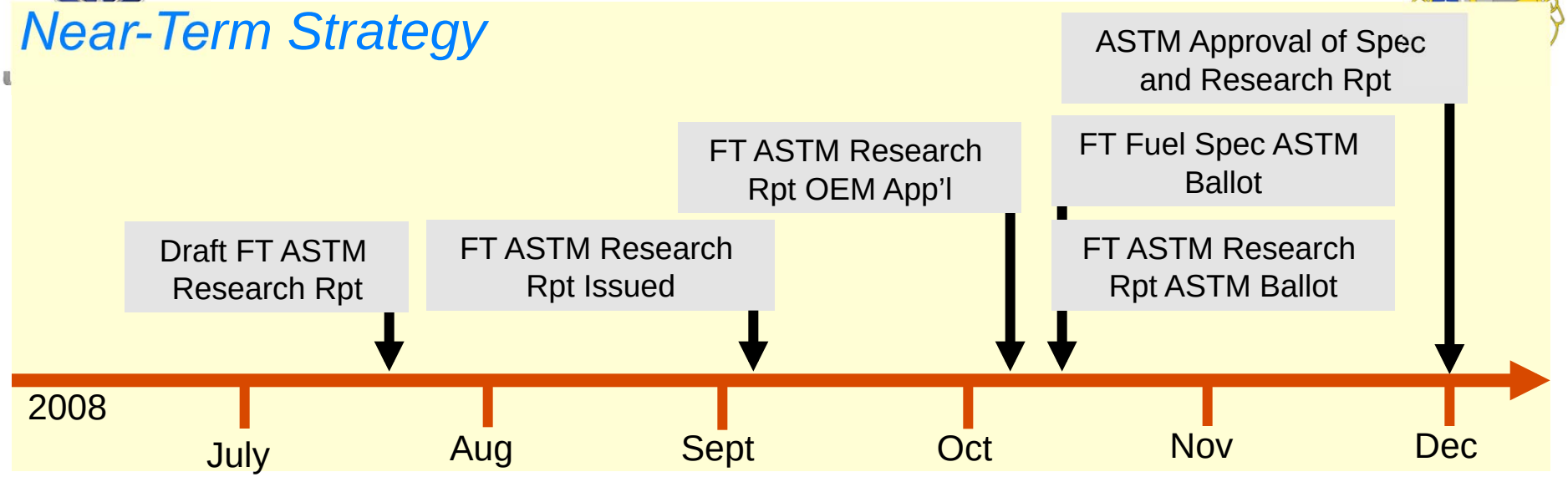
88ABW-2009-1702, 88ABW-2009-4026

AFRL Major Thrusts

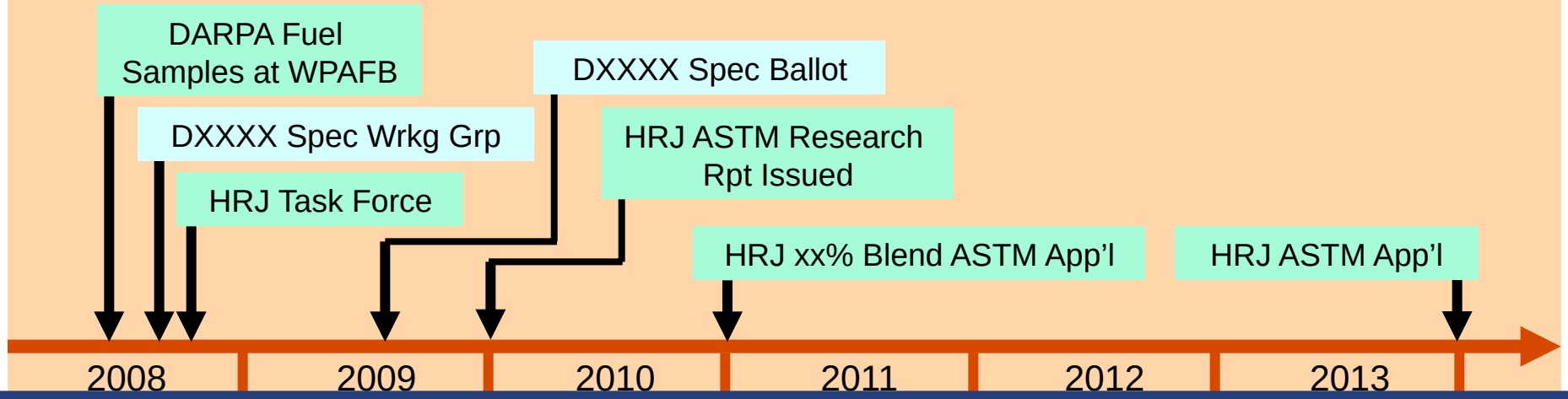
- **High level goals:**
  - **2011 – 50/50 F-T blend certification for all systems (Alternative Fuel Certification Office (AFCO))**
  - **2016 – 50% of domestic consumption contains synthetics (F-T + ?) (~400M gal), "greener" than petroleum, cost-competitive**
- **AFRL major efforts (joint w/ AFPET) (coord w/ CAAFI)**
  - **F-T certification support (properties, mat'l compatibility, toxicology)**
  - **Aviation biofuel certification**
  - **Key parameters**
    - **Performance ("drop-in")**
    - **Cost ("competitive")**
    - **Production potential ("significant")**
    - **Lifecycle greenhouse gas footprint ("less than petroleum")**
    - **Sustainability ("?")**

Timeline Summary

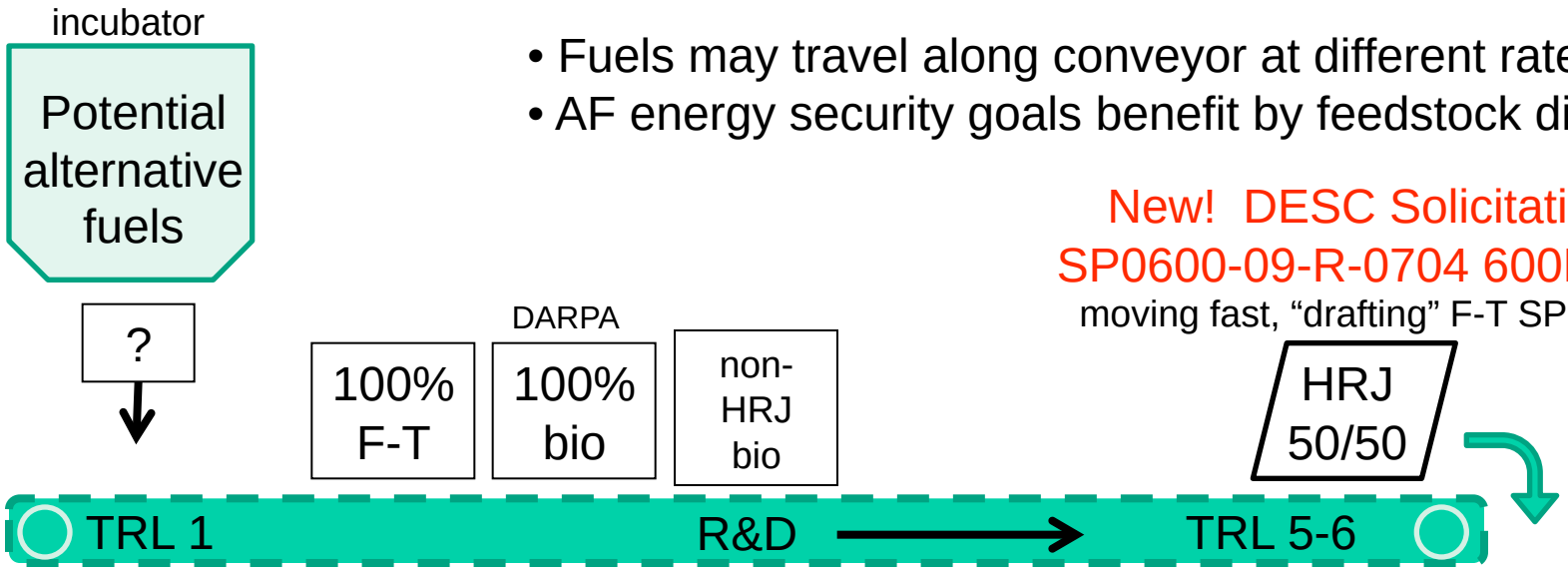
Near-Term Strategy



Longer-Term Strategy



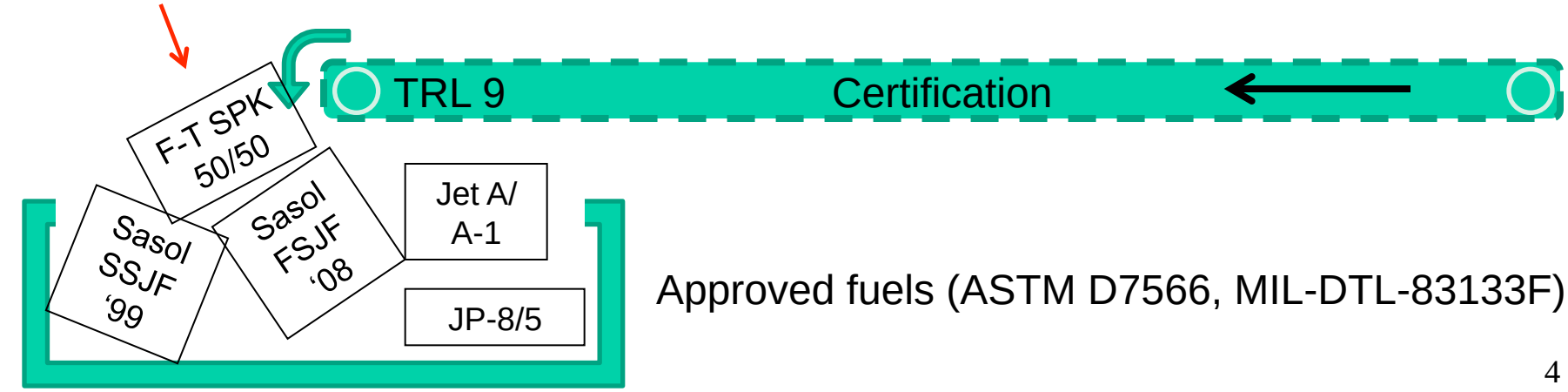
Certification "Pipeline"



- Fuels may travel along conveyor at different rates!
- AF energy security goals benefit by feedstock diversity

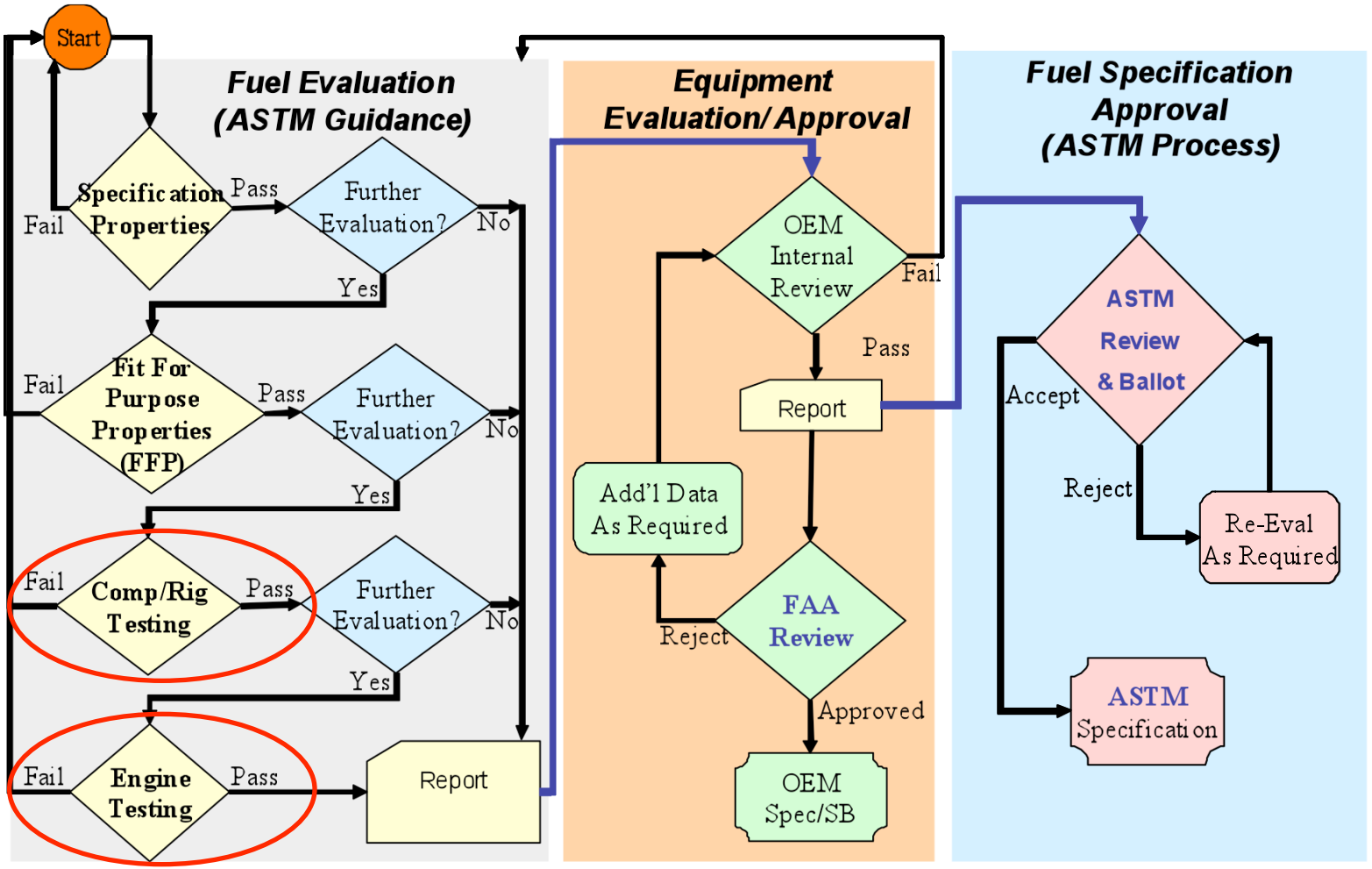
New! DESC Solicitation SP0600-09-R-0704 600K gal
moving fast, "drafting" F-T SPK

New! ASTM D7566



Approved fuels (ASTM D7566, MIL-DTL-83133F)

Certification Processes – MIL-HDBK-510, ASTM D4054



which rigs?

which engines?

Fit-for Purpose Properties

FIT-FOR-PURPOSE PROPERTIES

CHEMISTRY

- Hydrocarbon chemistry (carbon number, type, distribution)
- Trace Materials/Metals

BULK PHYSICAL AND PERFORMANCE PROPERTIES

- Boiling Pt Distribution
- Vapor/Liquid Ratio
- Thermal Stability Breakpoint
- Lubricity
- Response to Lube Improver
- Viscosity vs Temp
- Specific Heat vs Temp
- Density vs Temp
- Surface Tension vs Temp
- Bulk Modulus vs Temp
- Thermal Conductivity vs Temp
- Water Solubility vs Temp
- Solubility of Air (oxygen/nitrogen)

FIT-FOR-PURPOSE PROPERTIES

ELECTRICAL PROPERTIES

- Dielectric Constant vs Density
- Electrical Conductivity and Response to Static Dissapator

GROUND HANDLING/SAFETY

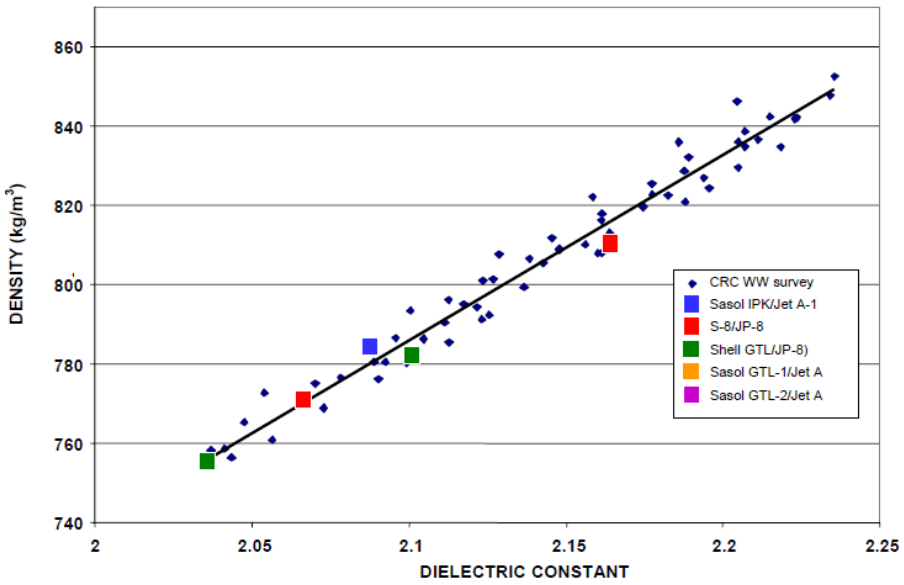
- Effect on Clay Filtration
- Fitration (Coalescers & monitors)
- Storage Stability
  - Peroxides
  - Potential Gum
- Toxicity
- Flammability Limits
- Autoignition Temperature
- Hot Surface Ignition Temp

COMPATIBILITY

- Other Additives/Fuels
- Engine/Airframe Seals, Coatings, Metallics

Research Reports

- **Used to support commercial specifications (data also used for military certification)**
- **Addresses whether "drop-in" fuels fall within experience base**



COMPARATIVE EVALUATION OF SEMI-SYNTHETIC JET FUELS

FINAL REPORT

Prepared for
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CRC Project No. AV-2-04a

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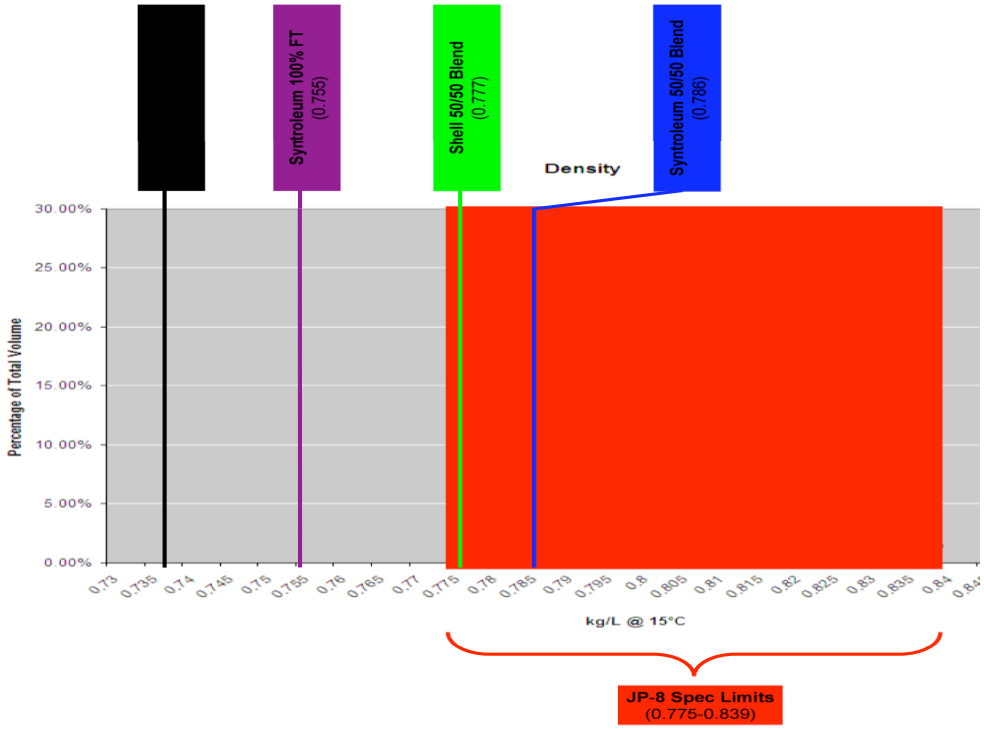
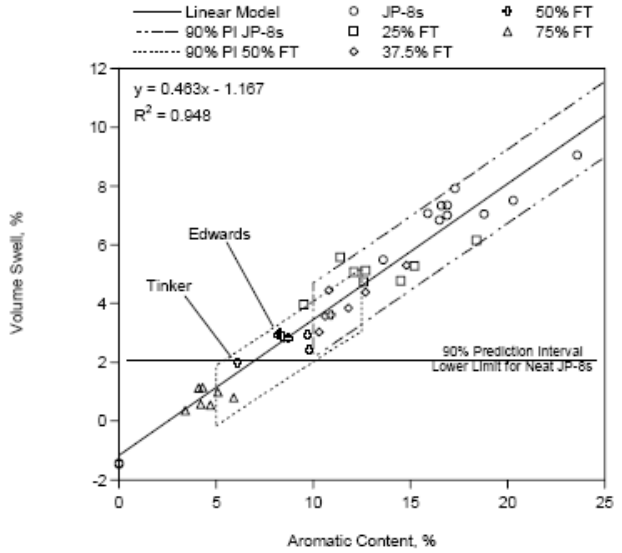
through Universal Technology Corporation

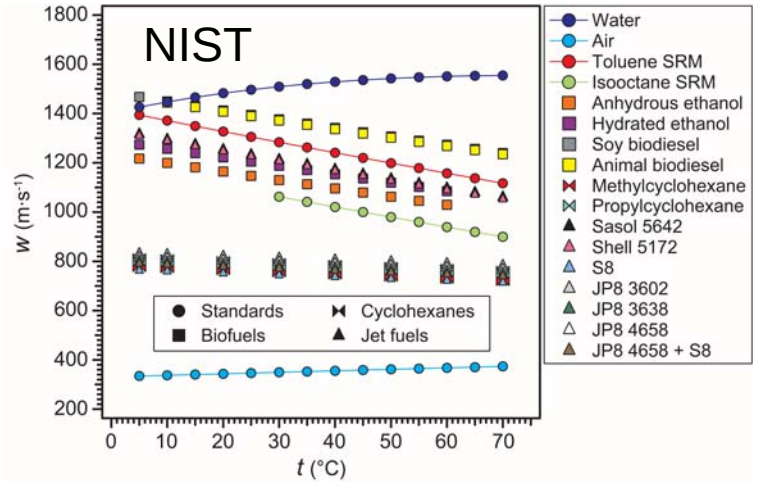
September 2008

Experience Base

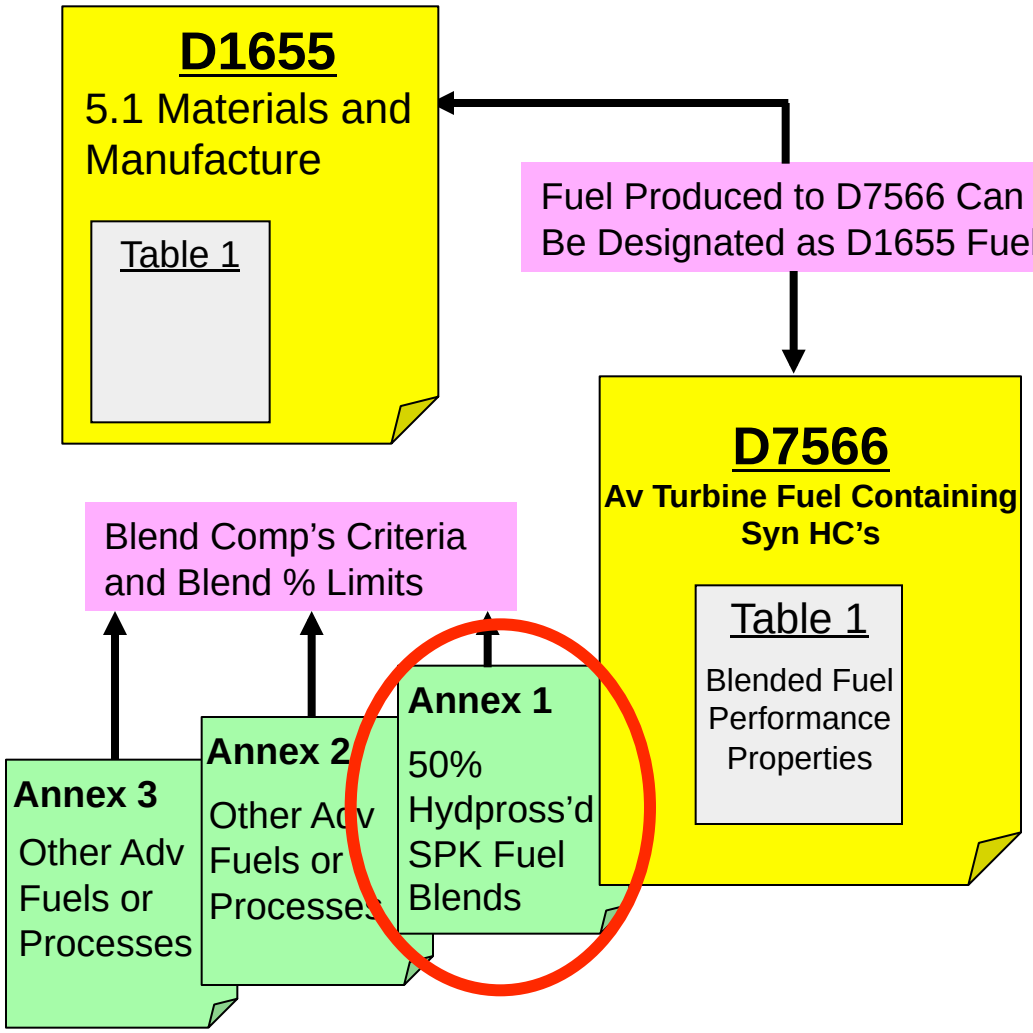
- **World Fuel Survey**
- **PQIS database**
- **Newly developed data**







ASTM D7566 Fuel Specification

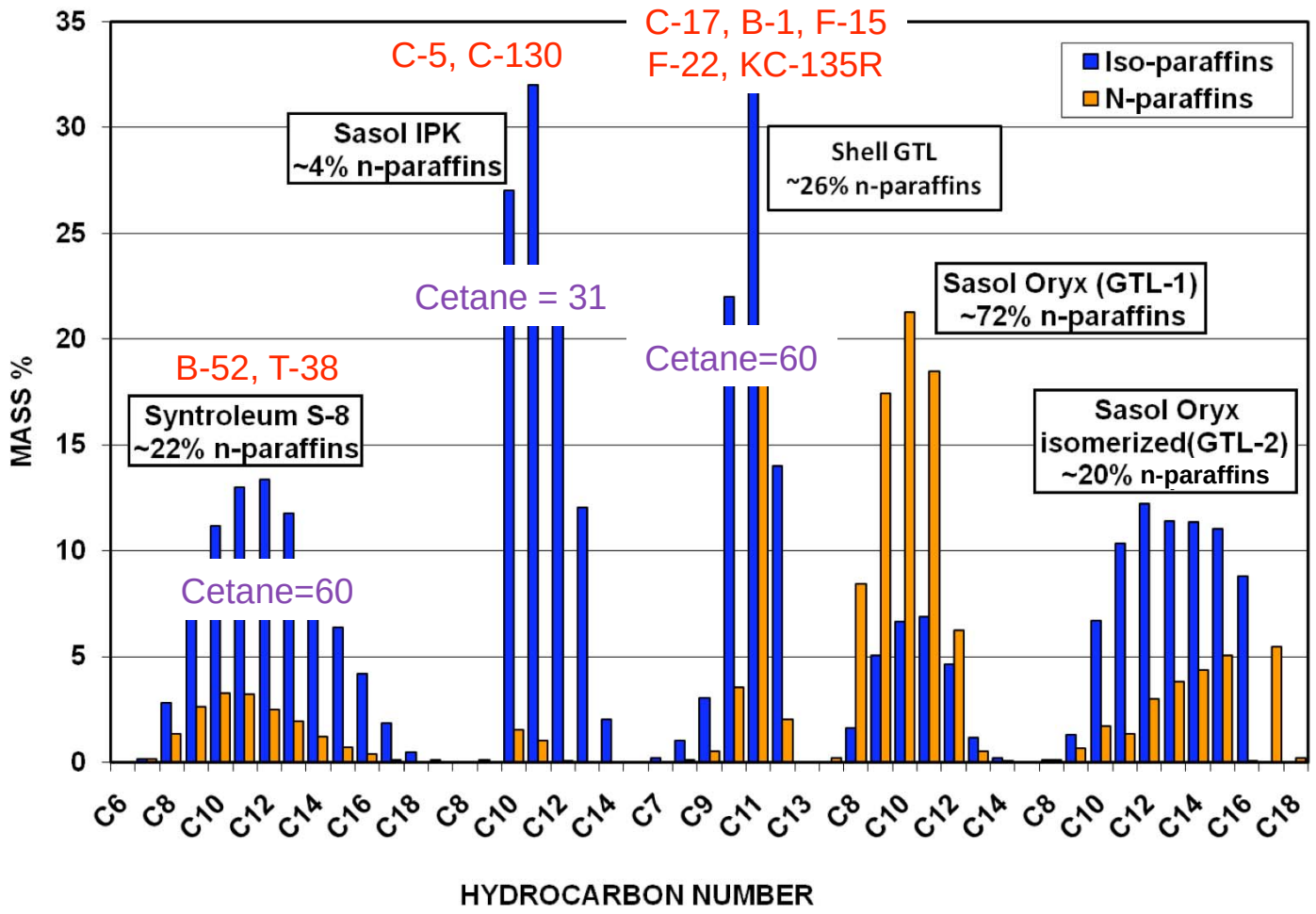


Key Provisions

- Body of Spec Applies to Finished Semi-Synthetic Fuel
- Annex for Each Class of Synthetic Blending Component
- Allow Re-Certification to D1655
  - No need for separate tracking
- Annex 1
  - Hydroprocessed SPK
    - **Includes 50% FT Fuel**
- Issued in August 2009
- Hydroprocessed Renewable Jet (HRJ) Added to Annex 1 in Next Revision

Baseline Fischer-Tropsch Fuels

- **Form basis of Research Report to support specification**



AFRL/RX Material Compatibility

50/50 Blend

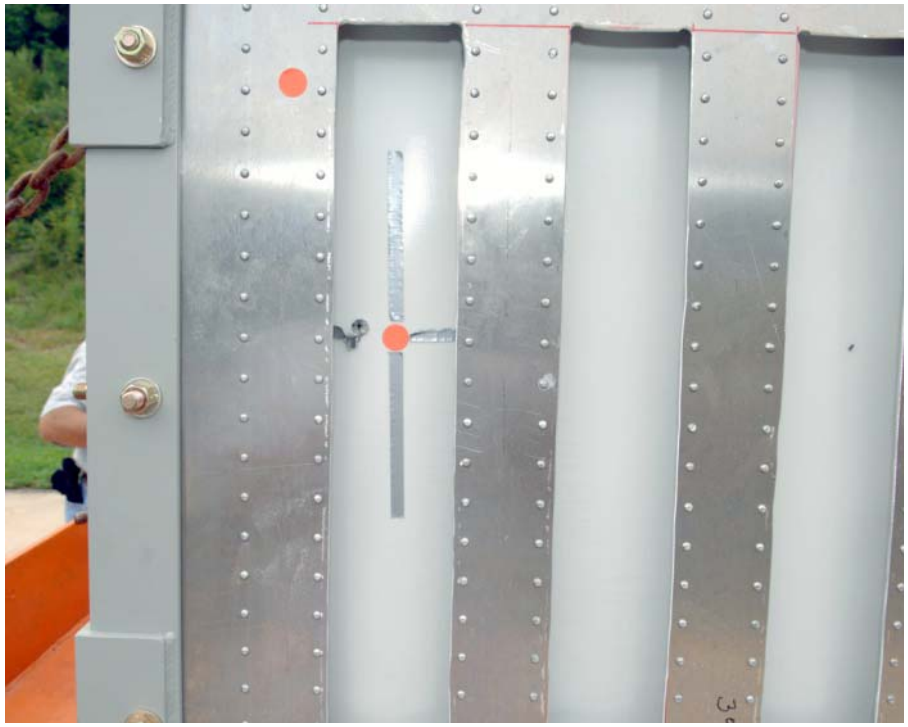
- **No serious concerns with any materials tested to date**
- **Still analyzing/testing any "Gaps" identified by various platforms and AFCO**

100% SPK

- **100% SPK (0% aromatics) fuel may not be feasible due to material compatibility issues**
- **Working with AFRL/RZ to investigate/identify the minimum aromatic content needed in the fuel**
  - **Is 8% the right number?**

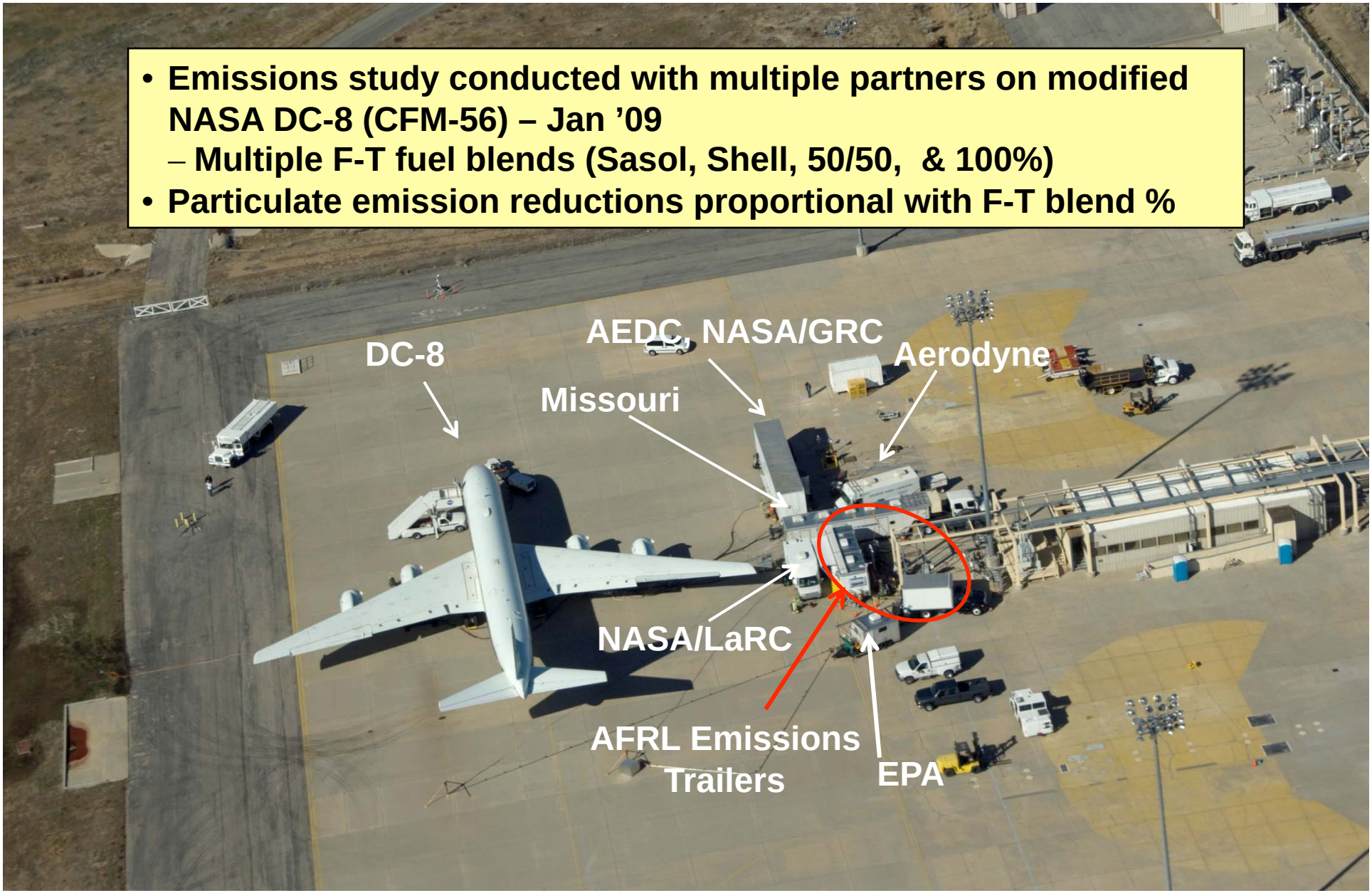
Self-Sealing Bladder Testing

- Evaluating self-sealing bladders as function of fuel aromatic level
- May be more constraining on aromatic level than o-rings



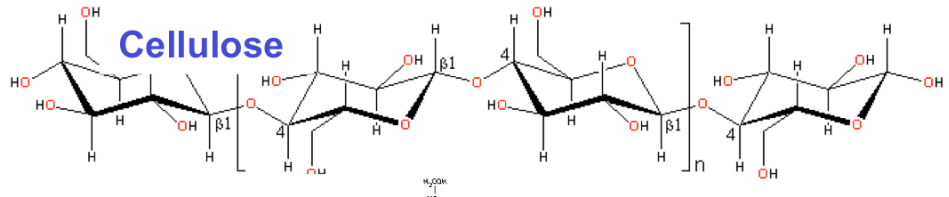
Emissions Collaboration

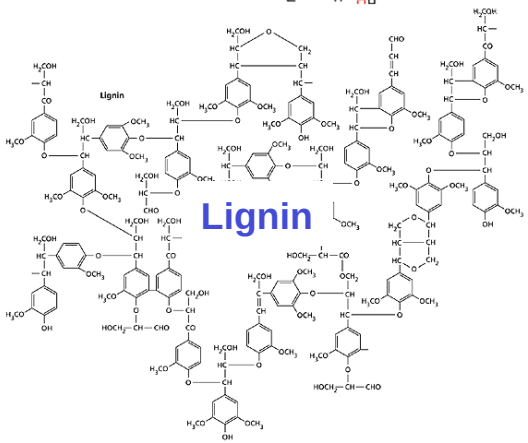
- **Emissions study conducted with multiple partners on modified NASA DC-8 (CFM-56) – Jan ’09**
  - **Multiple F-T fuel blends (Sasol, Shell, 50/50, & 100%)**
- **Particulate emission reductions proportional with F-T blend %**

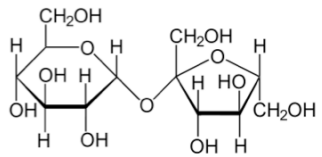


Beyond F-T – Biofuels!

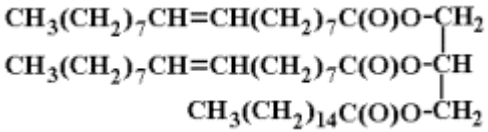
“second generation”







“first generation”



gasification
(or co-gasification
with coal)

pyrolysis

“HRJ”

hydroprocessing

$CO + H_2$

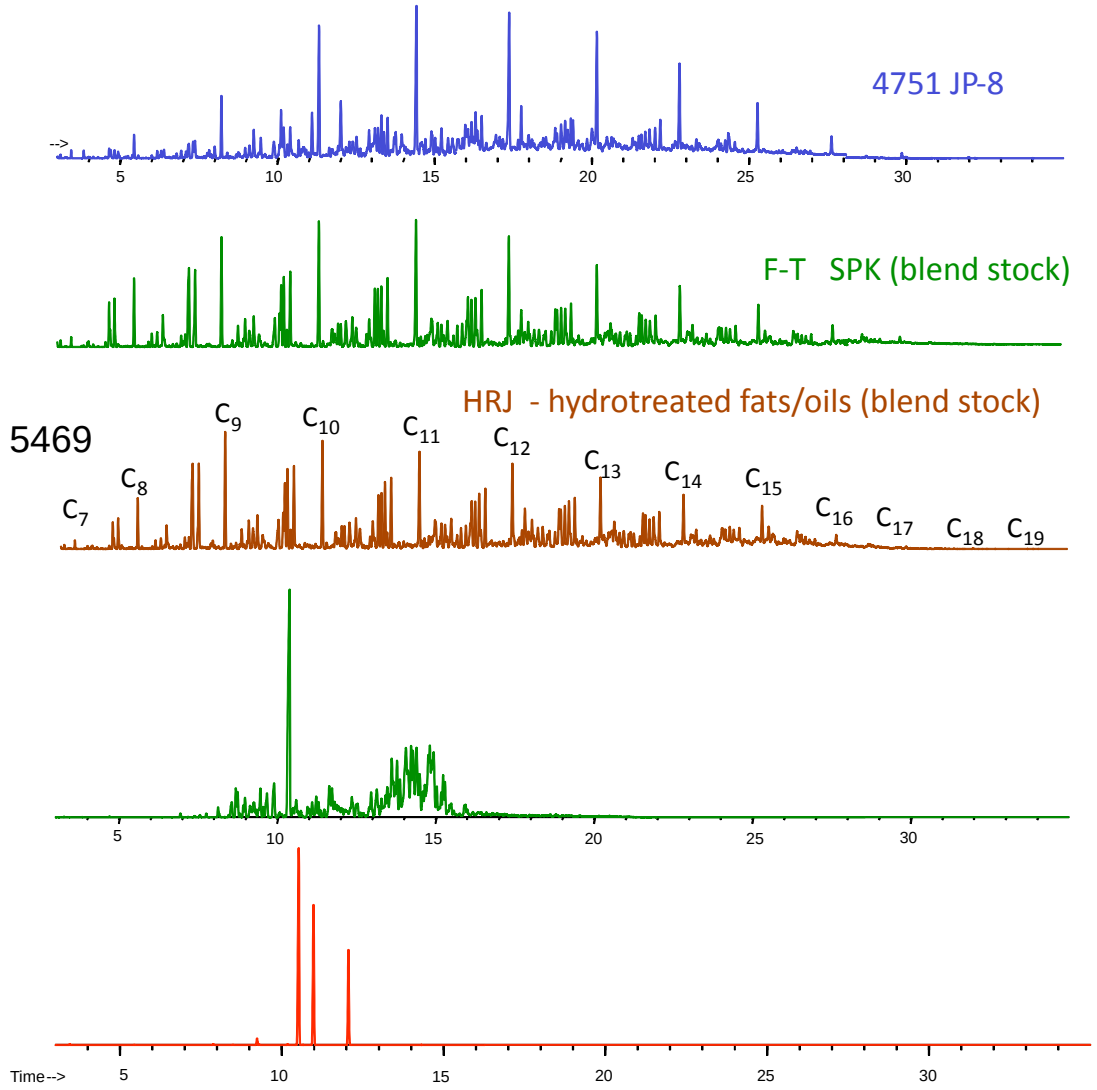
“BTL”

alcohols

“direct fermentation”

jet fuel
components

Alternative Fuels On-Going Analysis



TRL 9 –current fuels JP-8, Jet A

TRL 8 – generic F-T 50/50

TRL 5 (?) – HRJ 50/50 (flight demonstrated)

TRL 2

More Challenging Biofuels

TRL 2-3

Combustion Evaluation

Composition

- **Aromatics, cycloparaffins, *n*- and *i*-paraffins**
- **Hydrocarbon chain length**

Properties

- **Density vs T**
- **Viscosity vs T**
- **Flash point**
- **Heat of combustion**
- **Boiling range**
- **Vapor pressure**
- **Surface tension**
- **Cetane**
- **…**

Combustion Performance

- **Lean blow out**
- **Altitude relight**
- **Transient accel/decel**
- **Instability**
- **Emissions/efficiency**
- **Liner/nozzle heating**
- **Engine control response**
- **…**

Prototype Combustion Evaluation Process

Fundamental expts

fail

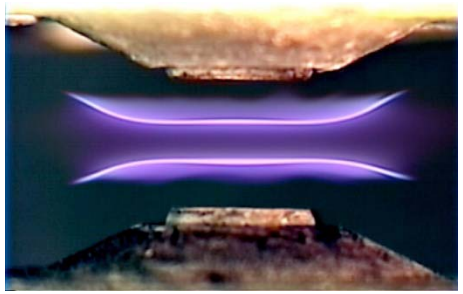
pass

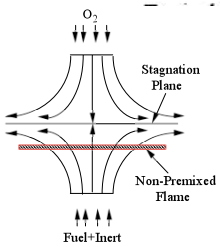
Flame tube rigs

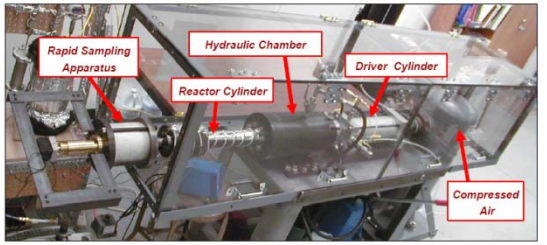
Sector rigs

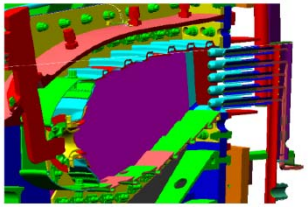
Full annular

Engines









H: FA8650-09-D-2925-0005
P: FA8650-09-D-2923-0010
G: FA8650-09-D-2922-0007
W: FA8650-09-D-2924-0006
R: FA8650-09-D-2921-0007

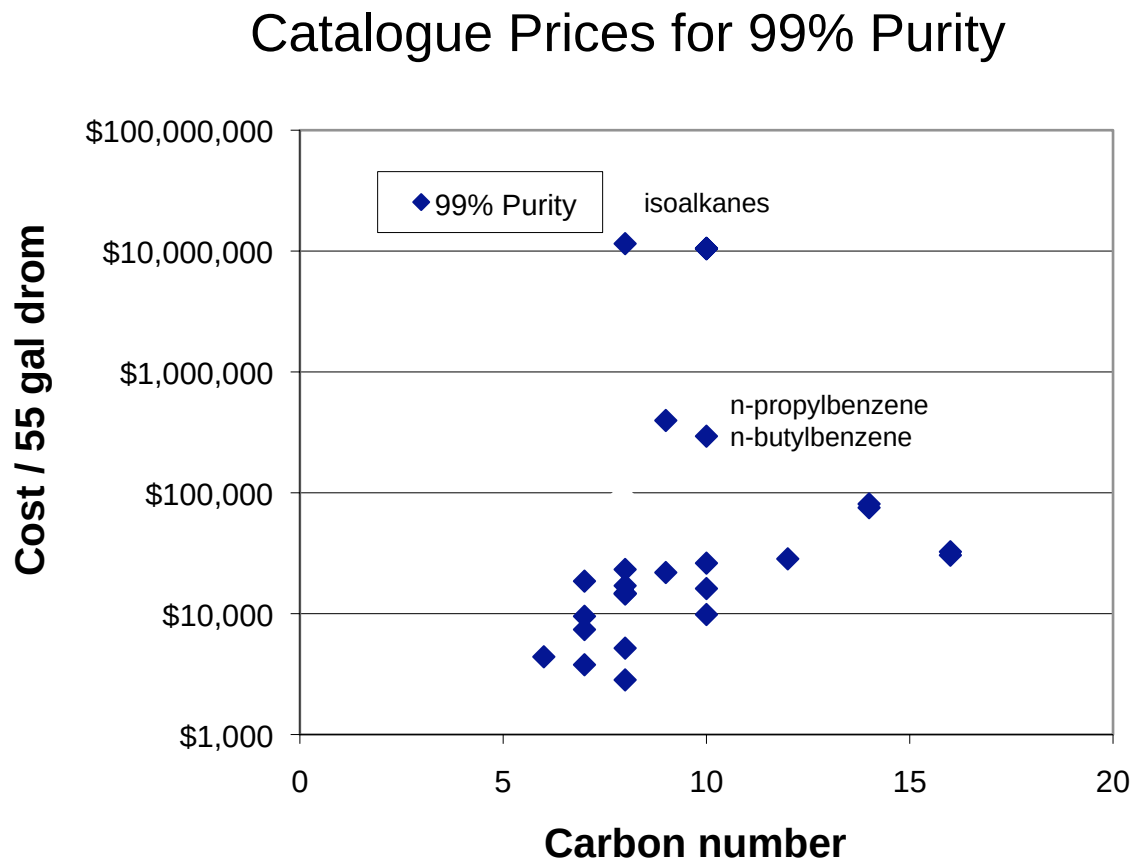
Reference Fuel Repository

- **Reference fuel repository being established for surrogate components**
- **Spreadsheet for components**
- **Issues: cost vs purity vs volume**
- **Plan:**
  - **Phase 1 – conventional components (n-alkanes, aromatics, etc.**
  - **Phase 2: I$oparaffin$**

Existing 40 F storage at WPAFB

7 drums MCH, 3 drums iso-octane

Repository or Ft Knox?



“Biocarbon” Analysis

- **ASTM D6866 assesses fraction of carbon that is “modern” using C14**
- **Initial assessment**

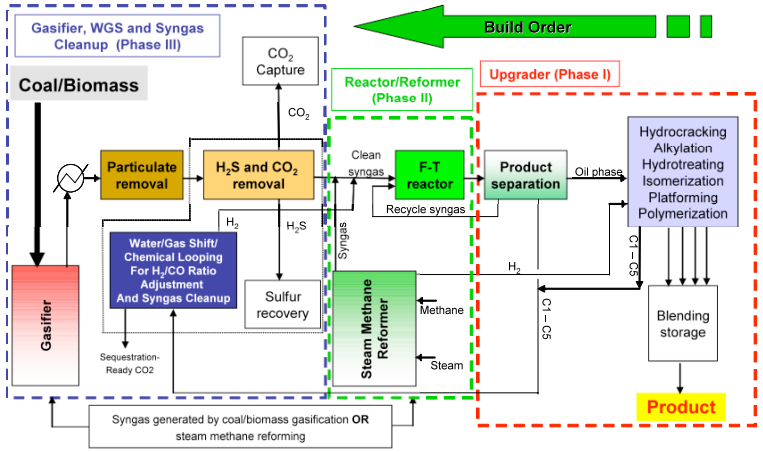
Fuel	Feedstock	% modern C
WPAFB JP-8	petroleum	0
Sasol IPK	coal	0
Shell SPK	nat. gas	0
Syntroleum R-8	fat/oil	96
R-8X	Salicornia	100
JP-8/R-8 50/50	blend	49
UOP DARPA “biojet”	bio + pet. aromatics	73

Summary

- **Interest in alternative fuels remains high**
  - **50/50 F-T blend is nearing transition**
- **Biomass-derived fuels are current S&T focus**
  - **“Drop-in” petroleum replacements/blendstocks are focus in near term – fully synthetic in mid term**
  - **Assessment criteria must be defined: performance, cost, manufacturing potential, GHG footprint, sustainability**
  - **Biofuels may not always be “greener” than petroleum or CBTL (w/CCS)**
  - **Scale-up/cost/land use issues**

Assured Aerospace Fuels Research Facility (AAFRF)

- **Description:** Research facility to assess properties and performance of alternative jet fuels from domestic feedstocks (Coal/ Biomass/Natural Gas)
- **Use:** Generate research quantities (15-25 gal/ day) of alternative jet fuel
  - Evaluate properties to optimize specifications for new types of fuels
  - Evaluate processing, catalysis and feedstock influence on fuel properties
  - Evaluate processes to enhance production of alternative jet fuels
- **Status**
  - Phase I installed at WPAFB
  - Phase II being assembled
  - Phase III undergoing conceptual design
  - Enclosure for housing AAFRF in detailed design




Phase I in Bldg 490

Alternative Fuels R&D Roadmap